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ABSTRACT

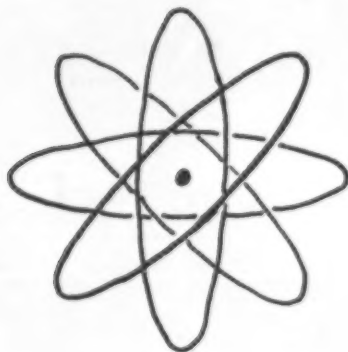
Radiation has been a serious concern to individuals for over 100 years. A process by which an atomic nucleus emits particles to reach a more stable energy state, radiation harms living cells (usually by inhalation and absorption into the lungs) by causing abnormal cell function and structure. Man is constantly exposed to background radiation, both naturally caused and manmade (nuclear power plants and weapons testing, consumer products, medical x-rays, etc.). Uranium mining and milling, an especially dangerous radiation-exposing activity, can be more safely pursued by using mechanical ventilation, isolation and diversion of the radiation source, air cleaning, respiratory protection, and job rotation. Radiation's health effects are numerous. Cancer studies around radiation sources reveal epidemics of respiratory disease and great danger when radioactive gases mix with other pollutants. Pregnant women are the most susceptible to radiation because division of the fetus's cells can greatly increase the damage caused from exposure. Research is still needed on the effects of nonionizing radiation sources (microwaves and radiowaves). Appendices include additional information on radiation measurement, organs at risk, naturally occurring radionuclides, decay series of Uranium-238, radiation exposure and responsible government agencies. (LC)

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RADIATION and Its Health Effects



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AUGUST 1980



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RADIATION AND ITS HEALTH EFFECTS

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I. INTRODUCTION

Radiation is a serious concern to all individuals living in the world today. Although many people may not want to think about it and let the government, the companies involved with nuclear power production and warheads, and anti-nuke groups deal with radiation, it can't be emphasized enough that RADIATION AFFECTS US ALL!

Every human body as well as those of any other living creature contains a certain amount of radioactive molecules. Some of these are natural and come from the natural radioactivity in the environment. However, these natural levels have been increased by man's experimentation with nuclear fission products, the testing of nuclear weapons, the generation of nuclear power, the medical use of radioactive materials, and research at universities. All of these activities produce radioactive waste, the disposal and storage of which is a serious problem. The EPA estimated that by the year 2000 approximately one billion cubic feet of low-level wastes will require disposal. Roughly, this volume is enough to cover a four-lane highway from coast to coast one foot deep. (13, p. 34)*

A concern about waste products of the entire nuclear fuel cycle is needed. We cannot concern ourselves only with the wastes products produced at a nuclear plant. We must look at everything that happens from the moment the uranium is taken out of the ground because radioactive waste is generated at each step. For instance, when pure uranium is removed from uranium ore, 85% of the radioactivity is left behind in the tailings. The wind can easily blow the tailings away and contaminate soil and water. According to a Ford Foundation Study, if the present legal limit for manmade, nonmedical radiation were to be reached through the use of nuclear power, an increase of 0.2 to 5.5% in the present incidence of 10 genetic abnormalities per 1,000 live births could result in the first generation alone. The damage would continue for 20 or 30 generations following irradiation. If this level were to continue for subsequent generations, genetic disease might occur at a rate 2-50% higher than presently observed. (1, p. 172)

Irrigating with contaminated water spreads the radioactivity to plants which in turn are eaten by people and livestock. Thus, radioactive elements not only spread through the food chain, but are re-concentrated in plants, livestock, and humans.

A major problem with radioactive elements is the long time it takes for them to decay (reach a stable state and no longer be radioactive). For some products it takes hundreds, thousands, or millions of years. This is why production of large volumes of radioactive waste is of serious concern. None of the presently active storage/disposal sites were chosen with optimum hydro-geologic ground characteristics in mind. (13, p. 134) Economic and political forces have dominated the selection of sites. (13, p. 135) Careless handling is extremely dangerous to the environment and health of living creatures. A leak or spill from a storage site can have grave ramifications.

(* Footnote numbers refer to sources as numbered in the Bibliography).

Although current levels in water, soil, or whatever, may be labeled "safe" now by the NRC, ICRP, EPA, or some other regulating agency, the levels will continue to rise because it takes so long for radiation to go away. And what of the additive effects? If you drink milk containing a safe level, eat a steak containing a safe level, and so on? Are they still safe when you add them all together?

Radiation does not only come from the nuclear fuel cycle and warhead production. Medical exposure is also a key factor in dose to humans. Many consumer products, such as TV tubes, give off low levels of radiation. Another large contributor (briefly described in Section VII of this paper) is nonionizing radiation. For instance, what are all those radiowaves out there doing to the environment?

It should be obvious that radiation is a complex problem with no easy answers. The following pages seek to explain what radiation is and some of its major sources.

II. A BIT OF HISTORY

Although concern over radiation has escalated in recent years, the dangers of radiation have been known for well over a hundred years.

Radioactive materials were first mined centuries ago in Jachymov (Joachimstal, Czechoslovakia) and Schneeberg (Tyrol, Austria). (20, p. 9) In 1531 Paracelsus described a lung malady that killed miners in the prime of their life. (6, p. 814) In the 19th century Madame Curie isolated radium and polonium from pitchblende found in Joachimstal. She eventually died of leukemia. During the period from 1875-1939, 43% of those European miners died from lung cancer. In 1950 the U.S. Public Health Service began a survey among uranium miners in the Colorado Plateau and found an increased incidence of lung cancer. The increase was linked to airborne radiation in the miners, particularly the radon daughters. (6, p. 185)

As time went on, other harmful effects of radioactive materials were realized: of x-rays in 1896, of radium in 1900, and of uranium fission products in 1944. X-rays were associated with abnormal redness, swelling, and death of the skin and later on with cataracts (1909). (6, p. 896-7) Radium was linked to inflammation of the skin and aplastic anemia* in the early twentieth century. In 1925 it was realized that gamma-rays could reach the bone marrow and cause leukemia. Thus, the first protection for those working with radioactive materials came into being. (6, p. 910-11)

Unfortunately, most of the knowledge of the harmful effects of exposure to radioactive materials were not realized until after they had occurred. In the 1920's, workers in New Jersey and Connecticut who painted watch dials with luminous paints containing radium salts began to show signs of disease. They developed anemia, their jaw tissue decayed and was easily fractured, and tumors of the bone appeared. The disease had been caused by the consumption of radium salts in the paint by pointing their paint brushes with their tongues. (6, p. 914) People working in the watch-dial industry are continually bombarded with alpha-particles from plutonium-239 and radium-226. (6, p. 917)

When nuclear fission was unlocked in 1939, the problem of huge emissions of energy arose. (6, p. 293) When the atomic bomb was exploded in 1945, anyone within 500 meters was instantly burned to death. Data has been collected from Nagasaki and Hiroshima and from accident victims in Los Alamos on exposure of the whole body to large amounts of radiation. (6, p. 924)

For centuries man has been dealing with radioactive elements and subjecting himself to its harmful effects without realizing it. The dangers were gradually figured out after the effects had occurred. People have often become guinea pigs through the general lack of knowledge of radiation and what it does.

However, today much trial and error still goes on. Even though scientific and medical technology have improved greatly since the 1920's and 1930s, much remains unknown. Despite the knowledge that had already been accumulated, when

*(The inability of the blood to properly regenerate itself which results in a decrease of red blood cells and/or hemoglobin.)

uranium mining was accelerated in the 50's, few precautions were taken to protect the miners. Now many of the miners who had worked in those mines have been dying of lung cancer and other radiation induced diseases. Part of the problem is that there is a fairly long latent period between the initial exposure and the onset of any disease. It's taken nearly 20 years for these diseases to show up. What other diseases may appear is not known. Also the genetic effects on future generations is not known.

Despite technological advances, the issue of what makes a dose dangerous continues today. Part of the problem is that radioactive monitoring is an imprecise science. Different types of radiation cause varying effects to various parts of the body and are registered differently by different detection devices.(13, p. 6) Also some organs are more sensitive than others. Certain radionuclides are "organ-seeking." Their chemical make-up causes them to prefer certain organs, i.e., strontium-90 is similar to calcium and gravitates to bone, and iodine-131 gravitates to the thyroid.(13, p. 18)

Models have been created in order to calculate doses to the body. In the past, a radiation "threshold hypothesis" was the model used to explain the induction of disease. The threshold hypothesis worked on the idea that under a certain level no damage was incurred or above a certain level disease would start.

The threshold hypothesis has been disregarded and replaced with the "linear hypothesis." The linear hypothesis assumes that the effects of low-level exposure can be determined (linearly extrapolated) from the known effects of high exposure. However, new information on low-level ionizing radiation exposure shows that the linear hypothesis does not work in some cases. Some believe that the hazard of low, extended doses of radiation may actually be greater than that of short, acute exposure (50 rems or more) because cancer-prone cells that might be killed by acute doses could survive low exposure and eventually become cancerous.(13, p. 20) But much remains unknown because studies have been inconclusive or have pointed in different directions. Other studies indicate that no threshold exists for radiation effects and, therefore, there is no "safe" dose.(13, p. 22)

Numerous committees have been established on a national and international level in order to investigate the dangers, establish maximum exposure rates, provide protection for those occupationally exposed, etc. The organizations include the International Commission on Radiation and Protection (ICRP), founded in 1928, the National Council on Radiation Protection and Measurement (NCRP), the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), The National Academy of Sciences Advisory Committee for Assessing the Biological Effects of Ionizing Radiation (BEIR), The Office of Radiation Programs included in the U.S. Environmental Protection Agency, and the U.S. Nuclear Regulatory Commission (NRC).

The levels set by the above agencies have recently come under criticism for being too low. In November of 1978, a team of 14 German scientists at the University of Heidelberg (agricultural biologists, physicians, physicists, chemists, mathematicians, etc.) released the "Heidelberg Report" which directly

challenges the NRC's calculations for radiation doses to the general public from the environmental contamination. The radiation doses received from routine releases from nuclear power plants and uranium mining and milling may be 10's to 1,000's times greater than federal regulations predict.(3)

The Heidelberg group states that the recommended factors for essential radionuclides (strontium-90, cesium-137, uranium-238, radium-226, thorium-230, and plutonium-239) for the transfer from soil into plants, from fodder into animal products, and from the gastrointestinal tract to the blood are sometimes determined in a scientifically questionable way. The values currently used are often in the lower end of the range of realistic values. A major problem is that once radionuclides get into the body, there is no way to actually detect levels. All doses are CALCULATED using some sort of model and several assumptions. (2)

One reason for the underestimates is that the chemical form of the radionuclides in the food chain is ignored. For example, plutonium-239 is taken up 1,000 times faster by humans when it is found in chlorinated water. For reasons such as this, each location and situation must be evaluated individually. The overestimations have resulted from generalizing factors. The soil conditions, the chemical form of the radionuclide, and other factors all vary with each location and, therefore, the site-specific studies are necessary.

Another problem is that radiation doses are calculated for an average individual. Differences in body structure, race, and sex are not considered. Nor are special groups such as the ill, the elderly, or the unborn included. People with a deficiency of a certain element will take up higher percentages of the radioactive isotope. For example, people with bone fractures take up strontium-90 ten times faster.(3)

Thus, the research group has labeled the environmental programs which monitor the radioactive releases from nuclear facilities as inadequate. Some contributing factors are the lack of sensitivity of equipment to low levels of cumulative amounts of radiation, insufficient understanding of interactions of radionuclides in the food chain, and often, a lack of financial backing to do comprehensive and site-specific monitoring.

III. RADIATION: WHAT IS IT?

Radiation literature is filled with all sorts of technical terms, most of which cannot be avoided. The next few pages give the reader a brief explanation of atomic structure and what ionizing radiation is.

Radiation is a property of the smallest particles which make up all matter in the universe, atoms. An atom is composed of a nucleus which contains neutrons and protons and orbiting particles, electrons.

The proton is a subatomic particle present in the nucleus of all atoms which carries a positive electric charge. The number of protons in an atom is known as the atomic number. The neutron is also a subatomic particle present in all atomic nuclei, but it does not carry an electric charge. Its mass is about equal to that of a proton. The atomic weight of an atom equals the number of protons and of neutrons. In order to appreciate the small size of these particles, it should be noted that the mass of the proton is 1.672×10^{-24} gm. The electron is a negatively charged particle which orbits the nucleus of the atom. An electron is nearly 2,000 times smaller than a proton. The negative charge on the electron is numerically equal to the positive charge on the proton, and thus, the presence of one proton and one electron will balance the electric charge on an atom.

An ion is created when an atom or group of atoms either gain or loses one or more electrons (which can be done fairly easily because the orbits of electrons are quite large and are relatively far from the nucleus). Radioactive emissions create ions and hence, the term ionizing radiation has come into use.

Elements are named on the basis of their atomic weight. For instance, carbon-12 has six protons and six neutrons. Carbon-14 is a radioactive element containing six protons and eight neutrons. Carbon-14 is said to be an isotope of carbon-12. Isotopes are elements which contain the same number of protons, but different numbers of neutrons. The chemical properties of isotopes are the same, even though one isotope may be radioactive while others are not.

Often the increase in the number of neutrons causes an unstable energy balance between the neutrons and protons within the nucleus. This imbalance can be corrected through the emission of particles from the nucleus. This is the definition of radiation--the process by which an atomic nucleus emits particles in order to reach a more stable energy state. Many elements, for instance, uranium-235, possess the nuclear imbalance and are the natural radioactive elements. Man has been able to create new elements by injecting or removing neutrons, thus causing instability and nuclear emission, (e.g. uranium-238 + one neutron $\rightarrow$ plutonium-239).

The emissions can be in various forms, alpha- and beta-particles, x- and gamma-rays. Alpha-particles are made up of two protons and two neutrons (the equivalent of a helium nucleus). Because of their relatively large size, they have a low penetrability and cannot penetrate the outer layer of dead skin.

Several sheets of paper can stop them. A beta-particle is a high-speed electron. A thin sheet of metal is needed to stop it. Gamma-rays are not particles. They are rays which travel at the speed of light. Their high speed gives them a high energy and, consequently, a great penetrating ability.

In the process of emitting particles in order to achieve a more stable state, radioactive elements go through a series of intermediates before arriving at the final product. Thus, the name, radioactive decay series. The series are named after the initial element. The process of radioactive decay can be extremely long. The half-life of an element is the time it takes for half of the original amount of material to turn into the stable end product. For example, the half life of uranium-238 to lead-206 is 4.51 million years. If one starts with a pound of uranium-238, 4.51 million years later one half of it would have decayed into other elements, and a half pound of uranium would remain. 4.51 million years later another half of that half pound of uranium would have decayed, and a quarter pound of uranium would remain. After the next 4.51 million years, one eighth of a pound of uranium would remain.

Protons are often ejected when they are struck by an ionizing particle. The proton has an important role in irradiation of the body because the body contains a large number of protons in the form of hydrogen nuclei. When the body is irradiated, most energy is imposed upon the hydrogen nuclei. Thus, the protons are a major pathway for transferral of energy to body tissue.

Such a transferral of energy is what makes radiation harmful to living cells. Many of the processes that occur at the cellular level are achieved and regulated through mechanisms which are based upon ions and changes in electric charge. Ionizing radiation can remove electrons and create abnormal combinations of molecules within the cell, disrupt bonds between atoms damaging complex molecules such as DNA, stimulate abnormal growth (cancer), and cause mutation of cells.

IV. BACKGROUND RADIATION

A. Natural Radiation

An important characteristic of radiation is that it is a natural process. Man is constantly exposed to background radiation from the air we breathe, the water we drink, the minerals in the soil, the building materials of homes, and the cosmic radiation striking the earth's outer space. It is man's interference and acceleration of radioactive decay that is causing serious health dangers and environmental instability.

Previously, natural radiation in the environment was known as background radiation. However, the term background radiation has come to include additional radiation in the environment created by human activity, such as nuclear weapons testing. This is important because radiation standards are often compared to background levels. However, are the background levels that are used for comparison the natural levels or are they natural levels elevated by human additions? One must be careful of this point. It also should be noted that measuring the environmental radiation field is extremely difficult because there are so many factors to include in the calculation.

How much background radiation an individual will receive depends on a number of factors such as altitude and location. People at higher altitudes are exposed to more cosmic radiation than those at sea level. The hourly dose rate at jetcruising altitudes is approximately one hundred times that at ground level. (14-B, p. 21) At sea level the cosmic radiation dose equivalent is at least 26 mrem/yr, while in Denver, at 5,280 feet elevation, it is at least 50 mrem/yr. (14-B, p. 21)

There are 17 natural radioactive elements. Only two of these play a significant role in dose to man, potassium-40 and rubidium-87. Some of these elements are made radioactive when cosmic particles strike them and cause a change in their energy properties. Four of these radionuclides are significant in giving a dose to man: carbon-14, tritium, sodium-22, and beryllium-7. The first three are especially important because they are isotopes of major elements of the body. Because isotopes (radioactive or not) behave the same way as the original element, the body cannot distinguish between them. For example, carbon-14 will be taken up and incorporated whenever the body uses carbon-12.

But very little of the population's dose from background radiation comes from the cosmic radiation. Most background radiation originates from radioactive elements in the soil which get into the air and water, into the food chain, and into building materials. The hydrosphere, the water vapor in the atmosphere and the earth's surface water, is also important because it is a major vehicle of movement for radioactive elements. Most radionuclides in soil water come from radon-222, radon-220, and radon-219. (14-B, p. 58)

Most soils have some radioactivity in them. Just how much depends upon the rock from which the soil originated and other variables. Most of the radioactivity in soils stems from potassium-40 and the decay products of uranium and thorium.

Geologic maps are often used to estimate the natural radioactivity of an area. But use of these maps can be misleading. A map will indicate the type and strength of radiation in the bedrock and not take the soil layers into account. For example, a soil layer of 0.25 m will give off radiation from the ground and mask bedrock with a higher or lower radiation level.(14-B, p. 54) Plants also take up radioactive elements from the soil and soil water. Plants prefer radium over uranium and radon daughters.(14-D, p. 22) The strength of the background radiation field is also affected by how much moisture is in the soil, whether or not there is snow cover and how much, and the concentration of radon in the air.

The decay products of the natural radioactive decay series are important contributors to background radiation. The uranium and thorium series are the primary contributors, especially the gaseous members, radon and thoron.

Although building materials might provide protection against outside radiation, they can create radiation fields themselves. Radium is frequently found in building material, especially concrete and gypsum block. If the home or structure is well ventilated, then the radioactivity of the building material plays a small role in dose to man.

Most radionuclides remain unimportant until they are inhaled and absorbed into the lung tissue.(14-B, p. 75) At least two-thirds of the radioactivity of inhaled aerosols (radioactive particles attached to ambient dust) ends up in the gut and at least one-third in the lungs. Almost all activity in the lungs eventually enters the blood and at least 8% of that deposited in the gut enters the blood.(14-B, p. 94) The daughter products, most commonly isotopes of lead, bismuth, and polonium can move from lung tissue to other organs. Uranium, radon, and thoron can become airborne only when they combine with dust particles. It is the airborne dust that controls the behavior of radioactivity in the air and lungs.(14-B, p. 76)

The ICRP has created a model for calculating the deposition of dust with a mass of average size in the respiratory tract, (i.e., the nasopharynx, the tracheobronchial region, and the pulmonary region). The dose to the lung is dependent upon where the material is deposited, how long it is there, and the strength of the energy that actually reaches the cells at risk. These levels are not known exactly: they must be CALCULATED.(14-B, p. 76) Alpha-particles are the most significant form of airborne background radiation.

B. Radiation From Human Activity

Manmade radionuclides are widely distributed in the environment. Nuclear weapons testing is a major source. The most common radionuclides and their sources are listed on the following page.

The decay processes of most manmade radionuclides have not been determined. Other manmade radionuclides which occur near nuclear facilities or weapons testing areas are xenon-138, xenon-133, krypton-88, cesium-139, rubidium-88, iodine-131, and argon-41. Barium-140, lanthanum-140, antimony-124, ruthenium-103, argon-41, and iodine-131 are widely distributed, but have a relatively short half-life. (14-D, p. 16) Usually a short half life is considered to be anything under 100 years.

COMMON RADIONUCLIDES AND THEIR SOURCES

Hydrogen-3; NE, NF	Antimony-125-Tellurium-125; NE
Carbon-14; NE, FF	Iodine-129; NF
Manganese-54; NE	Cesium-134; NE, NF
Iron-55; NE	Cesium-137-Barium-137; NE, NF
Cobalt-60; NE, NF	Cesium-144-Praseodymium-144; NE
Zinc-65; NE, NF	Protactinium-238; SNAP, NE
Krypton-85; NE, NF	Protactinium-239; NE, NF
Strontium-90-Yttrium-90; NE, NF	Protactinium-240; NE, NF
Zirconium-95; NE	Protactinium-241; NE, NF
Neodymium-95; NE	Americium-241; NE, NF
Ruthenium-106-Rhodium-106; NE, NF	

NE = nuclear explosion
 NF = nuclear facilities
 SNAP = system for nuclear auxiliary power
 FF = fossil fuel (14-D, p. 15)

V. URANIUM MINING AND MILLING

The U.S Army Corps of Engineers secretly began the Manhattan Project in the 1940's. The Manhattan Project involved top-secret research into atomic theory and nuclear fission which ultimately led to the development of the nuclear bomb. After World War II, from 1949 to 1957, the government stimulated a uranium boom.(20, p. 1) The uranium was used solely by the government for research purposes. Up until the late 1960's, the federal government was solely responsible for all mining of uranium. As of 1976, U.S. production of uranium employed about 3,000 underground miners.(20, p. 2)

The alpha- and beta-emissions from uranium series members are not intense enough to be a health hazard on their own. The greatest health hazard is caused by radon daughters (see explanation in the appendix) which attach to the dust in the mines.(20, p. 7) The dust is then inhaled and the radioactive molecules become lodged in the lung tissue. The molecules remain in the tissue and give off radiation to body parts.

Gamma radiation is of concern only in mines with extremely high grade ore. The whole-body exposure of 5 rems in any consecutive 12-month period is the limit set by the Radiation Protection Guide. This is subdivided into 2.5 mR/hr per 40-hour work week and 2.2 mR/hr per 48-hour work week.(20, p. 8)

The increased incidence of lung cancer among uranium miners has been linked to these radon daughters. Epidemiological studies among U.S. uranium miners, 1950-1968, showed an excess of respiratory cancer in all groups exposed to more than 120 Working Level Months (WLM) of radon daughter exposure. A Working Level Month is a designation for exposure to one Working Level (WL) of alpha energy from radon daughters for 170 hours, or one working month. (See Appendix 1) Respiratory cancers are continuing to appear at a high rate even though radon daughter levels have been reduced. The U.S. Public Health Service estimates that of the 6,000 uranium miners in the U.S., more than 600-1,100 have died or will die as a consequence of lung cancer from exposure to radon gas and its daughters in the 40's and 50's.(13, p. 35)

The major methods for controlling radon daughters are mechanical ventilation, isolation and diversion of the source, air cleaning, respiratory protection, and job rotation. Mechanical ventilation is the most important. Next is the isolation or diversion of radon from the main air streams in order to reduce the burden on the ventilation system.(7-E, p. 8)

Each mine has a primary and secondary ventilation system. The primary system is made up of high capacity fans at the surface which pull or push air through vent holes or shafts and through the main tunnels connecting with other vent holes where air is drawn in or discharged. The secondary system consists of small auxiliary fans within the mine which deliver air from the primary airways.(7-E, p. 9) Often the radon is contained by putting sealants on the rock which prevent the gas from escaping.(7-E, p. 9)

Uranium mill tailings are a sandy radioactive waste material left behind after uranium has been removed from the uranium ore. Currently there are over

140 million tons of tailings located at 35 sites in 9 Western states.(13, p. 135) High levels of radioactivity have been found in water supplies located downstream from old mill sites. Airborn radiation is high in the vicinity of tailings piles.(13, p. 135) About 85% of the radioactivity of the uranium ore remains in the tailings. Radium is the major radioactive waste. The tailings remain in open piles subject to wind and water erosion, ground water and soil contamination, and deliberate removal and unauthorized use.(21, p. i)

Although tailings are classified as low-level radiation, this does not necessarily mean that the radioactivity is evenly distributed. "Hot spots" or areas of higher concentrations can and do exist. The mill tailings generate radon gas up to 500 times that of natural background radiation. Considering the long half-life of uranium-238 (4.51 million years), the production of gas will last virtually forever.(13, p. 35) If tailings are not isolated from the environment, after 100,000 years they will become the greatest source of radiation exposure from the nuclear fuel cycle.(13, p. 38)

Until 1966, mill tailings were used for building foundation construction. In Grand Junction, Colorado, the Colorado Department of Public Health estimated that 10% of the occupants in those homes received the equivalent of more than 553 chest x-rays per year of gamma radiation.(13, p. 137)

VI. HEALTH EFFECTS OF RADIATION

A. The Toxicology of Uranium

Uranium and its salts are highly poisonous. Experiments with animals have shown that the salts attack the arteries, kidneys, and the liver. In 1854 Leconte first demonstrated that small amounts of uranium salts absorbed over a long period resulted in chronic inflammation of the kidney. Holman, in 1941 showed that dogs injected with uranium nitrate developed kidney lesions and severe decay of the arteries, especially the large elastic arteries. The liver also degenerated in dogs poisoned with uranium.(6, p. 494-6)

Sultzter and Hursh (1954) measured polonium excreted in the urine of miners working in the uranium mines of the Colorado Plateau. The polonium-210 was believed to have come from lead-210 stored in the bones. This lead-210 had come from radon daughter products deposited in the lungs and radon accumulations in the body fat.(6, p. 496)

Other work done with animals by Soviet researchers demonstrated definite disease-caused structural changes following poisoning with uranium. Poisoned with U_3O_8 inside the trachea, animals displayed damage to the membranes and the walls of the bronchials, inflammation of the mucous membrane around the bronchial tubes, U_3O_8 grain accumulations around the blood vessels and bronchial tubes, and a thickening of the air sacs of the lungs. Localized decay and degeneration of the kidney, inflammation near the minute blood filtering networks (glomeruli) within the kidney and poor protein nutrition of the liver (11, p. 133) were also found. In the lymph nodes and spleen the number of lymphoid elements was reduced, thereby affecting the body's defense mechanism. In the brain swelling around the vessels and cells, minor hemorrhages, hyaline clots in the vessels, and acute swelling and disruption of cells in important layers were discovered.(11, p. 134)

In comparison to naturally occurring uranium ore, the toxicity of spent fuel one year after discharge is almost 6 million times that of an equal weight of typical uranium ore containing 0.2% uranium-oxide. One million years later, the fuel is still more than 200 times as toxic as the ore.(13, p. 97)

B. The Toxicology of Radon

It was known in 1904 by the Soviet researchers, Professors London and Gol'berg, that frogs and white mice could be poisoned if they inhaled radon. Behounek and Fort studied Joachimstal miners and found that more than 50% of them had changes in their blood. Experiments conducted on animals have found an excess of blood in the inner organs, hemorrhages, and ulcerations in the intestine, extensive concentrations of decaying tissue in the bone marrow, a decrease in the number of small secretory sacs (follicles) and sometimes their total disappearance in the spleen and lymph system.(10, p. 147)

In other experiments where rats inhaled radon, acute centers of hemorrhage in all internal organs, emphysema, abscesses, and death in the lung tissue,

enlarged lymph nodes, a stagnant liver and purulent bronchitis (infection and inflammation of the bronchial tubes with pus) or peribronchitis (inflammation of the area surrounding and enclosing the bronchials) developed. Some of the work with rats showed that the pathological process in the lungs, due to radon, was not inhibited once inhalation had ceased, but progressed with slow, irreversible characteristics.(10, p. 158)

C. Cancer Studies Around Radiation Sources

Increased knowledge of and concern over nuclear power and its associated hazards have generated much interest recently both within the scientific community and within the public sector. The scientific community is divided as to what the effects actually are, what level is dangerous, and so on. The following are summaries of some of the studies currently being quoted or argued:

Dr. Joseph Wagoner

An individual who has been a forerunner in health studies on uranium miners is Dr. Joseph Wagoner, a graduate of Harvard University School of Public Health in Epidemiology. His work on uranium mining and milling began in 1960 when he joined the United States Public Health Service. The National Cancer Institute requested him to make sense of the health data that had been gathered on U.S. uranium miners. In 1969 the U.S. Surgeon General assigned him to study the radiation exposure standards in uranium mines and help update and lower those standards.

A New York Times article (May 20, 1979) stated that in 1974 Wagoner had counted 144 cancer deaths among 3,500 miners. Statistically 29.8 deaths should have been expected. Thus, 114 "excess deaths" had been caused by exposure to radiation in uranium mines. Of the 3,500 miners, 700-800 were Navajos. Two-hundred-fifty Navajos worked in the Kerr-McGee mine between 1952 and 1963.

The Navajo miners consult a doctor when they spit up blood--a sign of a cancer victim. Miners have reported that the mines have always been filled with much dust which made them cough and spit up black. They usually left work with a headache. The mines were cleaned up once a month when the federal inspectors were due to come in.

Miners also develop pulmonary fibrosis which takes longer to show up than cancer. The disease is caused by the radioactive particles which become embedded in the lungs. Scar tissue builds up around the particles.

In a presentation at the University of New Mexico's Medical School in Albuquerque, New Mexico, on March 10, 1980, Dr. Wagoner made the following points and expressed the following concerns.

He criticized the current maximum exposure to uranium miners (4 Working Levels (WL) or 120 Working Level Months (WLM) during 30 years). The level does not consider radiation from other radioactive elements which contribute about 2 rem/yr. Early miners received much higher exposures. In 1952 approxi-

mately 45% of the U.S. mines had radon daughter concentrations of 10 WL. In 1957, 44% of the miners were exposed to concentrations of 2.0-9.9 WL and 23% to levels over 10 WL. Now, despite federal regulations, there is a discrepancy between the levels reported by the companies to the Mine Safety and Health Administration and the levels found by actual spot checks taken by the government (the "blitz project," 1976-77). The spot checks found average exposures of 4.64 WL, while in 1977 the companies reported levels of 0.91 WL. Another factor is that the levels vary throughout the day. For instance, a 0.2 WL in the morning might go up to 17 WL during the first hour after lunch.

According to Wagoner, there is an epidemic of non-malignant respiratory disease as a result of employment in uranium mines. In studies of lung cancer deaths of U.S. uranium miners it was shown in 1964 that underground miners' risk of lung cancer increased ten times. In both non-malignant disease and respiratory cancer there is no increase in disease until 5 to 50 years after the onset of uranium mining. The risk of lung cancer begins to climb with succeeding years after the latency period has ended.

For awhile the mistaken idea that if a miner did not smoke he would not get lung cancer was circulated. This is not true. Miners who smoke develop lung cancer at an earlier date than the non-smoker. However, if the non-smoking uranium mining population is followed long enough, they suffer the same order of magnitude of radiation induced lung cancers as the smokers.

Despite much research in the U.S. and in other countries, the cancer induction level remains unknown. Wagoner questioned the adequacy of U.S. standards in uranium mines. He also warned against the occupational hazard to uranium mining and milling workers as well as the public health problem of hazardous waste disposal, such as tailings.

In Grand Junction, Colorado, homes have high levels of radon because tailings were used in the foundations. There, the mongolism rate in children is 3 times higher than that of the general population. Cleft palate incidence is also unusually high. There are homes on the Navajo Reservation built entirely out of tailings--what will this effect be?(??)

Dr. Ernest J. Sternglass

Dr. Ernest J. Sternglass is Professor of Radiological Studies, Department of Radiology at the University of Pittsburgh's School of Medicine. Dr. Sternglass's study has been met with much controversy and criticism of his data. Nevertheless, it is important to know what his study included.

Dr. Sternglass made a detailed study of cancer incidence near the Millstone Nuclear Power Station in Waterford, Connecticut. He investigated the cancer statistics in Connecticut and nearby New England and found that cancer mortality increased sharply around the two large nuclear reactors in direct relation to the measured pattern of accumulated levels of strontium-90 in the local milk. The strontium-90 levels in milk were the highest in Waterford and decreased as the distance from the reactor increased.

Operation for the reactors began in 1968 (Haddam Neck) and in 1970 (Millstone). Between the beginning of the operation and 1975, the cancer mortality rate rose 58% in Waterford, 44% in New London, 27% in New Haven, and 12% in Connecticut as a whole. Rhode Island rose 8%, Massachusetts rose 7%, New Hampshire rose 1%, Maine decreased 6%, and Vermont decreased 1%. (12, p. 174-5) In heavily polluted New York City, the cancer mortality rate decreased 2% in 1970-1975.

The dose to the bone and bone marrow was examined. The types of cancer which rose most strongly were the same as those types that have been determined to be most sensitive to radiation: cancers of the respiratory system, breast, and pancreas. (12, p. 176) Also a much greater rise in cancer death in women than in men was found. (12, p. 176) The cancer increase occurred most strongly in the same age groups which other studies by Milham and Mancuso (of employees at Hanford Reservation in Washington) had already shown to have cancer increases.

The range of the sensitivity of the individual can easily vary by a factor of 100-1,000. This is because the sensitivity is determined by a number of factors such as age, intensity of the radiation, the effect per unit absorbed dose, exposure of the developing fetus, and the reduced immune resistance of those over 65. (12, p. 178)

Sternglass believes that the most serious of all radiation exposures "are not brief medical x-ray diagnostic isotope tests for the adult, but prolonged environmental exposures to fallout accumulating in the body from nuclear bomb testing and releases from nuclear facilities acting slowly on the infant in utero, the young child, and the oldest individuals in our society." (12, p. 178)

He believes that those exposed to radiation combined with exposure to other known cancer promoting pollutants--chemicals, dusts, pesticides, sulfates, nitrous oxide--should have the highest cancer mortality rate.

"Thus, the combined action of airborne radioactivity and ordinary pollution would be greatest for those who live and work in the most polluted environment, who have the lowest socio-economic status, and, therefore, also the poorest medical care, so that they do not receive the benefit of early diagnosis and treatment." (12, p. 179)

The greatest increases in cancer have been in states with the largest nuclear facilities, (Hanford, Washington; Oakridge, Tennessee; Savannah River, South Carolina) or have nuclear reactors with known large releases in very densely populated areas such as those near the Millstone boiling water reactor (Connecticut and Rhode Island) and the Oyster Creek Reactor in New Jersey. Cancer mortality rates decreased in the four states with no nuclear facilities: Alaska, New Hampshire, Montana, and Hawaii. (12, p. 179)

In New York City, the two pressurized water reactors emit fewer radioactive gases than the boiling water reactors and are located 30 miles north of the city. The city showed a decrease of 1.1% in its cancer mortality rate despite its enormous air pollution and socio-economic problems. Sternglass believes this demonstrates that:

"When large amounts of radioactive gas releases are missing from the mix of pollutants, the resulting effect of cancer and other chronic diseases is much less than when radioactive gases act synergistically with dust, chemicals, cigarettes, and other air pollutants in the environment."(12, p. 181)

D. Radon Daughter Control

Sometimes radiation will appear where it is least expected. A case in point is a study that was done on reclaimed phosphate mining land. Uranium is often a natural part of phosphate rock. In the U.S. there are two regions where this occurs. One is in central Florida. The other is much larger and is included in Idaho, Montana, Wyoming, Utah, and Nevada.(14-B, p. 52)

A study was done in Florida where phosphate had been strip mined. The pit was filled with overburden that contained uranium. Homes were built on top of this "reclaimed mining" land, only to find that the buildings had unusually high radioactivity levels. The source of the radioactivity was the decay of radon-222 which in turn had come from the uranium in the land fill.(18-K, p. 6,9)

Thus, radioactivity and its harmful effects showed up in an area where it had not been anticipated. The agency which conducted the study concluded that the potential for construction of structures on reclaimed phosphate land is high.(18-K, p. 1) The methods used to control the radon daughters were forced ventilation, sealant, excavation, the construction of crawl spaces, and improved slab quality. A cost-effectiveness evaluation determined that crawl space construction was the best "optimal" control criteria.

E. Exposure of Pregnant Women

Radiation is particularly dangerous to rapidly dividing cells. Irradiation is most dangerous if it occurs during the week following conception because the number of cells is low. A small amount of damage early in pregnancy may have large delayed and cumulative effects as these cells further divide. Chromosomes are very susceptible to damage.(13, p. 18) For these reasons pregnant women should not be exposed to radiation. Women most often are exposed to rather high levels either from medical x-rays or at work.

At Work

In 1971 the NCRP published a dose limit of 0.5 rem over the entire nine months for women who are occupationally exposed. The council strongly recommends that any woman who can reasonably be expected to be pregnant should not be exposed to the same radiation environment as infertile women or men. These recommendations have been made with the main goal of protecting the unborn. The unborn is looked upon as being involuntarily subjected to radiation exposure.(14-E, p. 2) The limit applies specifically to the unborn and its entire development in the womb, rather than to the mother.

It is one thing to set the limit and another to practice it. Problems often arise with the communication between the employee and the employer. The employee may not be aware of the exact levels of radiation she is being exposed to, or of the potential effects upon her child, or she may not realize she is pregnant. An employer may not know that the employee is pregnant. However, the NCRP has taken the viewpoint that the unborn enters the radioactive environment involuntarily and not as a radiation worker. Thus, a conflict has arisen between the right to protect the offspring and the right of an individual to perform the work she desires without restraint under the provisions of equal employment rights laws.(14-E, p. 4)

Medical

A developing child is extremely sensitive to ionizing radiation, especially during the first week. Because of this the ICRP has decided that the possibility of pregnancy must always be considered by the attending doctor when the doctor is deciding whether or not to x-ray the lower abdomen and pelvis of a woman of reproductive age. The 10-day time period following onset of menstruation is the only time when it is most unlikely that a woman could be pregnant. Therefore, all x-ray examinations of the lower abdomen and the pelvis of a woman of reproductive age, not important in connection with the immediate illness of the patient, should be limited to that 10-day period.(16, p.304)

Radiation can induce genetic abnormalities. The ICRP has established that if the abnormalities are severe they can a) cause the failure of the fertilized egg to develop or the failure of the fertilized egg to attach to the uterine wall; b) cause the abortion of a fetus no longer able to live; c) permit development to continue and be expressed in a liveborn child.(7-G, p. 15)

The greatest danger of irradiation of the embryo, before it attaches to the uterine wall (implants), is the failure of the embryo implant. If the embryo does not implant, it cannot be hooked up to the placenta and, therefore, will not receive oxygen and nourishment from the mother.

The major risk to the embryo after implantation is malformation from damage during the major period of organ formation (35 days after implantation). Development after this stage is less clearly impaired, but damage can still be done to biochemical or local systems.

The irradiation at Hiroshima and Nagasaki has shown a decrease in head size and an increased incidence of mental defects.(7-G, p. 18) The greatest risk to the fetus is an increased death rate from malignant disease during the first 10 years of childhood.(7-G, p. 19)

The central nervous system begins its formation in the earliest stage of development and continues after birth. Thus, the central nervous system has a longer period of susceptibility to radiation. The embryo after 17 days and the fetus contain neuroblasts (cells which develop into nervous tissue) that are so radiosensitive that a dose of 25 rads can destroy them.

It is estimated that 80% of the malformations due to irradiation in the womb seem to be growth impairment, microcephaly (decrease in the size of the skull), and mental retardation. The risk of dying in the first 10 years of life has been observed to be doubled in studies on white children while no increase in deaths has been observed in blacks studied. The same holds true for the increased incidence of childhood leukemia. Neither blacks nor whites seem to exhibit an excess in any other cancer.(14-E, p. 23)

F. Consumer Products

There are many consumer products that emit ionizing radiation which, in many cases, is not needed to accomplish the purpose for which the product was designed.(14-G, p. piii)

Products which give off unwanted x-rays as by-products include television receivers, particularly color TV's, cold-cathode gas discharge tubes (used mostly in educational institutions to demonstrate physical phenomena), and electron microscopes.(14-G, p. 2, 7, 10) Products which intentionally emit x-rays are airport inspection systems, personnel scanning systems (used for security), and shoe-fitting fluoroscopes.(14-G, p. 12, 15, 17)

Products which contain radioactive materials in order to make them glow include wristwatches with luminous hands and dials which have been painted with paint containing radium-226 (until 1967) or tritium, pocket watches and clocks, portable and marine compasses, thermostats, light switches, automobile shift quadrant and lock illuminators, gunsights and aircraft safety devices, and static eliminators.(14-G, p. 19, 22, 23, 24) Smoke detectors give off alpha-radiation. (14-G, p. 26)

Natural radioactive materials are present in any of the following: Tobacco products contain lead-210 and polonium-210. Building materials contain uranium, thorium, and potassium.(14-G, p. 29) Highway and road construction materials made from some granites and phosphates can be radioactive. (14-G, p. 31) The combustion of coal gives off radium-226, thorium-226, and radioactive isotopes of lead and polonium in the fly ash.(14-G, p. 32) The combustion of oil and natural gas also gives off natural radionuclides. (14-G, p. 36, 37) Glass, ceramics, and porcelain used for dentures, tiles, etc., contain uranium salts.(14-G, p. 39, 40) Optical glass, gas mantles, tungsten welding electrodes, and various metal alloys may contain thorium. (14-G, p. 43)

The total average annual contribution to the whole-body dose equivalent of the U.S. population from consumer products is supposed to be less than 5 mrem. About 70% of this arises from naturally occurring radionuclides in building materials.(14-G, p. 54)

These products have been divided into two groups.

Group I - many people, and dose equivalent is relatively large.

- a) electron microscopes
- b) radioluminous products
- c) tobacco products
- d) building materials
- e) glass and ceramics

Group II - many people but dose equivalent is relatively small or, the dose equivalent is relatively large but the number of people involved is small

- a) TV receivers
- b) cold cathode gas discharge tubes
- c) airport inspection systems
- d) high voltage vacuum switches
- e) shoe-fitting fluoroscopes
- f) check sources
- g) static eliminators
- h) spark plug eliminators
- i) gas and aerosol detectors
- j) highway and road construction materials
- k) aircraft transport of radioactive materials
- l) contaminated raw material
- m) combustible fuels (14-G, p. 54)

VII. BRIEF INTRODUCTION TO NONIONIZING RADIATION

Nonionizing radiation has an energy much lower than ionizing radiation and, therefore, it cannot create ions like ionizing radiation does. Energy is transferred primarily through atomic vibrations and rotations.(18-L, p. 1)

Radiowaves are a major source of nonionizing radiation. Non-government users include business radio services, broadcasting stations (AM, FM, UHF, VHF), and AT&T.(18-L, p. 6) There is a scarcity of data defining the electromagnetic environment in the air to which the public is continually exposed.(18-L, p. 21) It has been known since WWII that electromagnetic energy in the radiofrequency and microwave section of the spectrum have dangerous effects on human tissue. Warnings against overexposure state the possibility of developing cataracts and of temporary sterility.(18-L, p. 48)

A problem exists in defining 1) the radiofrequency exposure to humans in our environment, and 2) the relationship between the potential exposure as calculated from technical data on a particular source and the actual human exposure of individuals living and working in a true exposure area.(18-L, p. 61)

The most powerful sources of radio frequency waves are satellite communication sections.(18-L, p. 61) However, other sources include electrocautery devices (used to cauterize people) and diathermy apparatus (used to generate heat in body tissues), electric shavers, internal combustion engine (the type of engine most commonly used in cars), ignition systems, radar, microwave ovens, and shoplifting alarms.(18-L, p. 72, 87) Cardiac pacemakers disfunction due to external electromagnetic interference.(18-L, p. 72)

No one really knows the effect of long-term exposure to very low levels of microwave radiation.(18-L, p. 94) Microwave and radiofrequency radiation generate heat in the organism. At high levels, pathologically observable lesions appear and secondary injury from overheating and cataract formation result. More subtle changes are not known.(18-L, p. 124)

APPENDIX 1

RADIATION MEASUREMENT

Absorbed Dose - the amount of energy imparted to matter in a region; not uniform; measured in rads.

Curie - a unit of radiation equal to the decay of 1 gram of pure radium per second; thirty-seven billion disintegrations/second.

micro-curie - 1 millionth

nano-curie - 1 billionth

pico-curie - 1 trillionth

As radioactive material disintegrates over time, the number of curies in it decreases. This unit of measurement does not indicate the type of radiation given off or how concentrated the field of radiation is.

Dose - the amount of energy absorbed.

Dose Equivalent - a common scale for all ionizing radiation. Because of the different natures of the particles, some particles produce a greater effect even though the same amount of energy is transferred. In order to arrive at the dose equivalent, the absorbed dose must be multiplied by certain factors. Dose equivalents are given in rems. For Beta-particles, x- and gamma-rays, rads are about equal to rems.

MEV (Million Electron Volts) - an electron volt is the charge on an electron.

Rad (Radiation Absorbed Dose) - A rad measures the dose of radiation to body tissues in terms of the energy absorbed per unit mass of the tissue. The absorption of 100 ergs per gram of tissue equals one rad.

Rem (Roentgen Equivalent, Man) - a measurement of the biological effect on a human being of any ionizing radiation. This measurement is a calculation, not a reading off of a radiation measuring instrument. One rem measures the biological impact of 1 roentgen of gamma rays under certain specified conditions. One millirem (mrem) = 0.001 rem.

Roentgen (R) - the basic unit of x-ray or gamma-radiation. Exposure usually measured in millir/hour.

Roentgen = 0.87 rad to air

0.96 rad in tissue

For tissue, roentgen exposure is equal to the absorbed dose in rads.

Spent Fuel - irradiated reactor fuel that has been removed from the reactor core.

Spent Fuel Pool - a pool of water, similar to a swimming pool, located adjacent to the reactor building, into which freshly discharged spent fuel is placed, in order to allow the radioactivity and thermal levels to decay to manageable levels.

Working Levels (WL) - any combination of short-lived radon daughters that produce 1.3×10^5 MeV in 1 liter of air of potential alpha energy.

Working Level Month (WLM) - exposure to radon daughter concentration of 1 WL for 170 hours (a working month).

APPENDIX 2

ORGANS AT RISK

Annual dose equivalent limits have been set for all workers and for each organ or tissue. The following is a list of the organs at risk and what the major effects are.

Gonads (ovary and testis) - subject to tumor induction; hereditary effects in descendants; have a low sensitivity to induced cancer; impaired fertility in the irradiated individual; (for women fertility impairment varies with age in that if two women were to receive an equal dose, a woman of 36 would be more likely to have an induced menopause than of woman of 20); are involved in the production of radiation induced gene mutations and chromosomal changes and thus, transfer hereditary effects. (7-F, p. 9, 10)

Red Bone Marrow (soft tissue within the cavities of bone which produce red blood cells) - radiation induced leukemia--incidence peaks within a few years after irradiation and returns to preirradiation levels after about 25 years.

Bone - radiation sensitive, particularly the tissue containing blood vessels (the endosteal) and the epithelial* cells on the bone surface. (7-F, p. 10)

Lung - miners exposed to radon daughters have an increased incidence of lung cancer.

Pulmonary Lymphoid Tissue (lymph tissue associated with the lungs) - retention of inhaled particles containing insoluble compounds in the lymph nodes associated with the lungs and bronchial tubes.

Thyroid - (endocrine gland located at the base of the neck which regulates metabolism and growth) - epithelial cells of the follicles are affected. (7-F, p. 11)

Breast - females of reproductive capacity are more radiosensitive.

Other tissues - stomach, lower large intestine, salivary glands, and the liver. (7-F, p. 12)

The ICRP recommends a maximum permissible dose (MPD) for the exposure received by an individual:

Gonads and red bone marrow = 5 rems

Hands, forearms, feet, and ankles = 75 rems

Skin, thyroid, and bone = 30 rems

All other organs = 15 rems (6, p. 907)

*epithelial cells - cellular tissue that covers free surfaces or lines cavities--often secretes or excretes, e.g., skin, mucous membrane.

The NCRP has set 15,000 mrems (or 15 rems) in any one year as the MPD for the internal or external exposure of any tissue, organ, or organ system not singled out. (16, p. 57) The cancer risk does not peak until 20 years after exposure. (16, p. 58)

APPENDIX 3

THE SEVENTEEN NATURALLY OCCURRING RADIONUCLIDES

Vanadium-50

Indium-115

Lanthanium-138

Neodymium-144

Gadolinium-152

Lutecium-176

Platinum-190

Bismuth-209

Rubidium-87

Cadmium-113

Tellurium-123

Cesium-142

Samarium-147

Hafnium-174

Rhenium-187

Platinum-192

Potassium-40

APPENDIX 4

THE DECAY SERIES OF URANIUM-238 TO LEAD-206 WITH THE HALF-LIVES AND THE RADON DAUGHTERS

<u>Element</u>	<u>Radon Daughter</u>	<u>Half-Life</u>	
Uranium-238 γ		4,510,000	years
↓ α			
Thorium-234 γ		24.1	days
↓ β			
Protactinium-234 γ		1.2	minutes
↓ β			
Uranium-234 γ		247,000	years
↓ α			
Thorium-230 γ		80,000	years
↓ α			
Radium-226 γ		1,622	years
↓ α			
Radon-222		3.8	days
↓ α			
Polonium-218	RaA	3.0	minutes
↓ α			
Lead-214 γ	RaB	26.8	minutes
↓ β			
Bismuth-214 γ	RaC	19.7	minutes
↓ α			
Polonium-214	RaC'	0.00016	seconds
↓ α			
Lead-210 γ	RaD	22	years
↓ β			
Bismuth-210	RaE	5.02	days
↓ α			
Polonium-210 γ	RaF	138.3	days
↓ α			
Lead-206	RaG	Stable	

α = alpha-emission
 β = Beta-emission
 γ = gamma-emission

Adapted from a variety of sources.

RaC' is the highest energy emitter. In uranium mines, for instance, the atoms attach to dust particles. It is estimated that at least 25-50% of the radon daughters are retained in the lungs. One WLM is the equivalent of about 2 rads averaged over the entire tracheobronchial epithelium. (20, p. 14) Federal and state agencies require explicit exposure records to be kept on each individual miner entering areas with radon daughter concentrations greater than 0.30 WL. (20, p. 36)

APPENDIX 5

RADIATION EXPOSURE AND RESPONSIBLE GOVERNMENT AGENCIES

<u>EXPOSURE</u>	<u>RESPONSIBLE GOVERNMENT AGENCY</u>
In uranium mines -	Bureau of Mines (DOI), Labor Department MSHA, NRC, PHS, DOE, EPA, State agencies
Population exposure in city 51 miles from a nuclear reactor	EPA, BRH, HEW, DOE, NRC, State agencies
Transportation of radioactive materials	DOT, EPA, NRC, DOE, State agencies
Permanent disposal of radioactive waste	EPA, DOA, DOE, DOT, NRC, ICC, State
Dangerous or ineffective use of radioisotopes, e.g., AM-241 in smoke detectors	DOE, HEW, HUD, NRC, OSHA, NIOSH, State agencies
Excessive medical exposure of members of the public	EPA, BRH, State agencies (up until recently, essentially no control)

Adapted from chart in Radiation Standards & Public Health - Proceedings of a
Second Congressional Seminar in Low-Level Ionizing Radiation, February 10, 1978,
page 10.

NRC - Nuclear Regulatory Commission -
ICC - Interstate Commerce Commission
PHS - Public Health Service
HUD - Housing & Urban Development
DOE - Department of Energy
OSHA - Occupational Safety & Health Administration
EPA - Environmental Protection Agency
NIOSH - National Institute of Occupational Safety & Health
BRH - Bureau of Radiological Health (FDA)
MSHA - Mine Safety & Health Administration
HEW (HHS) - Health & Human Services
DOT - Department of Transportation
DOA - Department of Agriculture
DOI - Department of Interior

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